INTERNATIONAL STANDARD

ISO 17201-1

Second edition
2018-11

Acoustics — Noise from shooting ranges —

Part 1: **Determination of muzzle blast by measurement**

Acoustique — Bruit des stands de tir —

Partie 1: Mesurage de l´énergie sonore en sortie de bouche

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 17201-1:2005), which has been technically revised. It also incorporates the Technical Corrigendum ISO 17201-1:2005/Cor 1:2009.

The main changes compared to the previous edition are as follows:

— the complete document has been editorially revised;

— 5.1, especially Figure 3 and the attached formula have been technically revised;

— Annex A (informative) "Small arms glossary" has been revised editorially;

— Annex B (informative) has been technically revised;

— references have been updated.

A list of all parts in the ISO 17201 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The initiative to prepare a standard on impulse noise from shooting ranges was taken by AFEMS, the Association of European Manufacturers of Sporting Ammunition, in April 1996 by the submission of a formal proposal to CEN. After consultation in CEN in 1998, CEN/TC 211, *Acoustics* asked ISO/TC 43/SC 1, *Noise* to prepare the ISO 17201 series.

To obtain reliable data for the prediction of shooting sound levels at a reception point, the energy of sound emission produced by the muzzle blast is needed. The muzzle blast is produced by the propellant gas expelled from the barrel of a weapon; in most cases the gas has a supersonic fluid speed. Close to the muzzle, the sound pressure is very high and cannot be described with linear acoustics. For the purpose of this document, the non-linear region is defined by the observation of a peak sound pressure level of 154 dB or more. This document defines how the sound source energy and directivity of the muzzle blast can be obtained from the measurement of sound exposure levels and how these measurements are to be carried out. The source energy, its directivity and spectral structure can be used as input for sound propagation models for environmental noise assessment. This cannot be used for calculations of sound exposure levels close to the weapon, for instance to estimate injury to people or animals.

Acoustics — Noise from shooting ranges —

Part 1:
Determination of muzzle blast by measurement

1 Scope

This document specifies a method to determine the acoustic source energy of the muzzle blast for calibres of less than 20 mm or explosive charges of less than 50 g TNT equivalent. It is applicable at distances where peak pressures less than 1 kPa (equivalent to a peak sound pressure level of 154 dB) are observed. The source energy, directivity of the source and their spectral structure determined by this procedure can be used as input data to sound propagation programmes, enabling the prediction of shooting noise in the neighbourhood of shooting ranges. Additionally, the data can be used to compare sound emission from different types of guns or different types of ammunition used with the same gun.

This document is applicable to guns used in civil shooting ranges but it can also be applied to military guns. It is not applicable to the assessment of hearing damage or sound levels in the non-linear region.

Suppressors and silencers are not taken into consideration in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
sound pressure
p
difference between instantaneous total pressure and static pressure

Note 1 to entry: The sound pressure is expressed in pascals (Pa).

Note 2 to entry: Static pressure is the pressure that exists in the absence of sound waves.

Note 3 to entry: This definition applies to a medium allowing a non-zero mean flow in the atmosphere.

Note 4 to entry: This definition is technically in accordance with ISO 80000-8:—[1)], item 8-2.2.

Note 5 to entry: For the definition of "static pressure" see ISO 80000-8:—, item 8-2.1, with the difference of allowing non-zero mean flow.

3.2
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the root-mean-squared sound pressure, p_{rms}, to the square of a reference value, p_0

$$L_p = 10 \lg \frac{p_{\mathrm{rms}}^2}{p_0^2} \text{ dB} \tag{1}$$

Note 1 to entry: The sound pressure level is expressed in decibels (dB).

Note 2 to entry: The sound pressure is expressed in pascals (Pa).

Note 3 to entry: For sound in air and other gases, the reference sound pressure is given by p_0 = 20 µPa.

Note 4 to entry: The sound pressure level can be frequency weighted and time weighted.

Note 5 to entry: This definition is technically in accordance with ISO 80000-8:—, item 8-15.

[SOURCE: ISO/TR 25417:2007, 2.2, modified — “the sound pressure, p” has been replaced with “the root-mean-squared sound pressure, p_{rms}”; the wording “where the reference value, p_0, is 20 µPa” has been removed; the original NOTE 1 and 2 have been removed; Note 1, 2, 3, 4 and 5 to entry have been added.]

3.3
peak sound pressure
p_{peak}
maximum absolute *sound pressure* (3.1) during a stated time interval

Note 1 to entry: The peak sound pressure is expressed in pascals (Pa).

[SOURCE: ISO/TR 25417:2007, 2.4, modified — The word “greatest” has been replaced with “maximum”; the word “certain” has been replaced with “stated”; NOTE 2 has been removed.]

3.4
peak sound pressure level
$L_{p,\mathrm{peak}}$
ten times the logarithm to the base of 10 of the ratio of the square of the *peak sound pressure*, p_{peak} (3.3) to the square of the reference value, p_0

$$L_{p,\mathrm{peak}} = 10 \lg \frac{p_{\mathrm{peak}}^2}{p_0^2} \text{ dB} \tag{2}$$

Note 1 to entry: The reference value is given by p_0 = 20 µPa.

Note 2 to entry: The peak sound pressure level is expressed in decibels (dB).

Note 3 to entry: Peak sound pressure should be determined with a detector as defined in IEC 61672-1; IEC 61672-2 only specifies the accuracy of a detector using C-weighting.

[SOURCE: ISO/TR 25417:2007, 2.5, modified — The wording “where the reference value, p_0, is 20 µPa” has been removed; the original NOTE has been removed; Note 1, 2 and 3 to entry have been added.]

1) Under preparation.

3.5
event duration
T
stated time interval, long enough to encompass all significant sound of a stated event

Note 1 to entry: The event duration is expressed in seconds (s).

3.6
sound exposure
E_T
integral of the square of the *sound pressure*, *p* (3.1), over a stated time interval or *event duration*, *T* (3.5), starting at t_1 and ending at t_2

$$E_T = \int_{t_1}^{t_2} p^2(t)\mathrm{d}t \tag{3}$$

Note 1 to entry: The sound exposure is expressed in pascal-squared seconds (Pa^2s).

[SOURCE: ISO/TR 25417:2007, 2.6, modified — The original NOTE 1 to 4 have been removed; Note 1 to entry has been added.]

3.7
sound exposure level
$L_{E,T}$
ten times the logarithm to the base 10 of the ratio of the sound exposure, E_T (3.6), to a reference value, E_0

$$L_{E,T} = 10\lg\frac{E_T}{E_0}\,\mathrm{dB} \tag{4}$$

Note 1 to entry: The sound exposure level is expressed in decibels (dB).

Note 2 to entry: For sound in air and other gases, the reference value is given by E_0 = 400 μPa^2s.

Note 3 to entry: This definition is technically in accordance with ISO 80000-8:—, item 8-17.

[SOURCE: ISO/TR 25417:2007, 2.7, modified — The original NOTE 1 to 3 have been removed; Note 1, 2 and 3 to entry have been added.]

3.8
source energy
Q
total sound source energy of the event

Note 1 to entry: The source energy is expressed in joules (J).

3.9
source energy level
L_Q
ten times the logarithm to the base 10 of the ratio of *source energy, Q* (3.8), to the reference source energy, Q_0

$$L_Q = 10\lg\left(\frac{Q}{Q_0}\right)\mathrm{dB} \tag{5}$$

Note 1 to entry: The source energy level is expressed in decibels (dB).

Note 2 to entry: The reference value is given by $Q_0 = 10^{-12}$ J.

3.10
angular source energy distribution
$S_q(\alpha)$
acoustic energy radiated from the muzzle blast into the far field, per unit solid angle

Note 1 to entry: The acoustic energy radiated by the muzzle blast within a narrow cone centred on the direction α (3.14) is:

$$S_q(\alpha) = \frac{dQ}{d\Omega} \tag{6}$$

where

Q	is the *sound energy* (3.8);
Ω	is the solid angle expressed in steradians.

Note 2 to entry: The angular source energy distribution, $S_q(\alpha)$, is expressed in joules per steradians (J sr^{-1}).

Note 3 to entry: Rotational symmetry is assumed around the line with $\alpha = 0$.

3.11
interpolated angular source energy distribution
$\bar{S}_q(\alpha)$
continuous function in α of the *source energy distribution* $S_q(\alpha)$ (3.10) derived by using a defined interpolation method

Note 1 to entry: The interpolated angular source energy distribution, $\bar{S}_q(\alpha)$, is expressed in joules per steradian (J sr^{-1}).

3.12
angular source energy distribution level
$L_q(\alpha)$
angular source energy distribution (3.10), given by ten times the logarithm to base 10 of the ratio of *angular source energy distribution*, $S_q(\alpha)$ (3.10) to the reference value, S_{q_0}

$$L_q(\alpha) = 10\lg\left[\frac{S_q(\alpha)}{S_{q_0}}\right]\text{dB} \tag{7}$$

Note 1 to entry: The angular source energy distribution level, $L_q(\alpha)$, is expressed in decibels (dB).

Note 2 to entry: The reference value is given by $S_{q_0} = 10^{-12}$ J sr^{-1}.

3.13
interpolated angular source energy distribution level
$\bar{L}_q(\alpha)$
continuous function in α of the *angular source energy distribution level, $L_q(\alpha)$* (3.12), derived by using a defined interpolation method

Note 1 to entry: The interpolated angular source energy distribution level is expressed in decibels (dB).

3.14
angle alpha
α
angle between the line of fire and the line from the muzzle to the receiver

Note 1 to entry: The angle alpha is expressed in radians in all formulae.

3.15
angle beta
β
angle describing the rotation around the line of fire, anticlockwise from the view of the shooter

Note 1 to entry: The angle beta is expressed in radians in all formulae.

3.16
angle gamma
γ
angle describing the inclination of the line of fire from the horizontal plane

Note 1 to entry: The angle gamma is expressed in radians in all formulae.

Note 2 to entry: See Figure 3.

3.17
angle delta
δ
angle constituted by the projection of angle α on the horizontal plane

Note 1 to entry: The angle delta is expressed in radians in all formulae.

Note 2 to entry: See Figure 3.

3.18
directivity
$D(\alpha)$
difference between the *angular source energy distribution level* (3.12) of the source under test and the source energy distribution level of a monopole source with the same acoustic source energy

Note 1 to entry: The directivity is expressed in decibels (dB).

3.19
muzzle distance
r_m
distance measured from the muzzle to the microphone point

Note 1 to entry: The muzzle distance is expressed in metres (m).

Note 2 to entry: See Figure 3.

4 Gun and ammunition

4.1 General

The information given in 4.2 to 4.6 is needed to unambiguously define the weapon plus ammunition combination for which the sound exposure level of the muzzle blast is estimated. All terms have the meanings given in Reference [14] and Annex A.

4.2 Gun

The following features shall be stated:

— description or brand name;

— type of gun (shot gun, rifle, revolver, pistol, etc.);

— calibre or gauge;

— barrel bore;

— barrel length.

The following feature should be stated:

— number, type and disposition of barrels (side-to-side, superposed, drilling, etc.).

If present, special features such as the following shall be mentioned:

— flame shield;

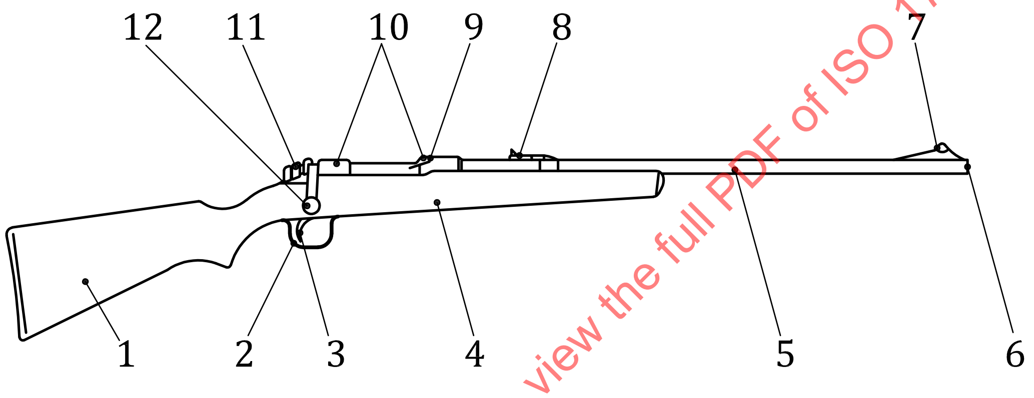
— muzzle brake.

Special features such as the following should be mentioned:

— choke;

— reload system.

Figure 1 is a schematic view and gives the main terms used to describe the gun.



Key

1	stock	7	front sight
2	trigger guard	8	rear sight
3	trigger	9	bolt
4	magazine (inside)	10	receiver
5	barrel	11	safety lock
6	muzzle	12	bolt handle

Figure 1 — Main terms used to describe the gun (schematic view)

The main parts of smooth-bore barrel and a rifled barrel are given in Annex A.

4.3 Ammunition

The following information is needed and shall be stated:

— description or brand name;

— projectile calibre;

— projectile mass.

The following additional information should be given:

— type and mass or chemical energy of propellant;

— type of projectile (ball, sabot, pellets or blank).

In case of shot guns (shot pellets), the following additional information shall be stated:

— type, number, size and weight or type-number of pellets.

In case of shot guns (shot pellets), the following additional information should be stated:

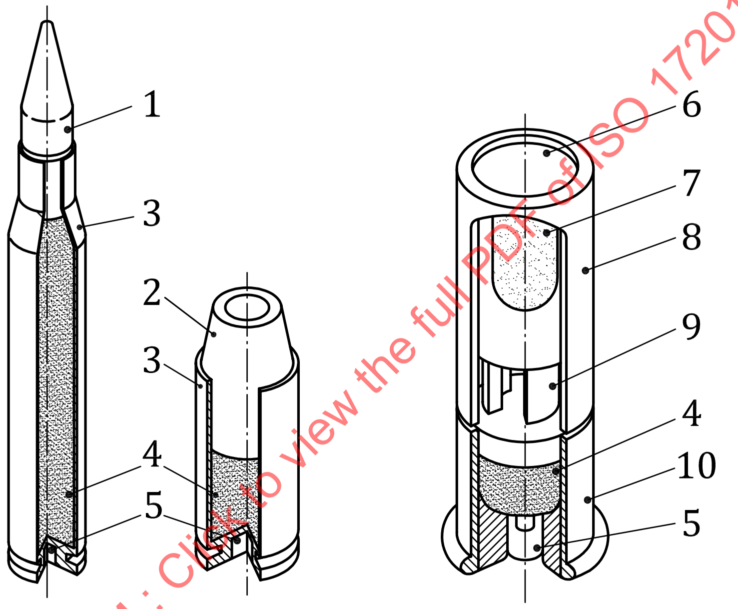
— total length of the cartridge and the gauge;

— type of tube;

— type of wad;

— type of crimping.

Schematic views of ammunition for rifles, pistols and shotguns are shown in Figure 2, with names of their main components.



Key

1 projectile (bullet) for rifle
2 projectile (bullet) for pistol
3 case
4 propellant
5 primer
6 tube
7 shot pellets
8 plastic cylinder
9 wad
10 case head

NOTE The measurements can be influenced by conditions such as the heating of the barrel during repetitive shooting, the temperature, the humidity and the age of the ammunition.

Figure 2 — Schematic view of ammunition

4.4 Ballistic parameters

The muzzle speed (speed of the projectile at the muzzle), as a result of a gun/ammunition combination as specified by the manufacturer, shall be stated.

Other available ballistic parameters should be stated.

NOTE Muzzle speed is a calculated value that corresponds to the speed of the projectile itself for rifles, or to the speed of the centre of gravity of the cloud of pellets close to the muzzle of a shot gun.

4.5 Test situation

Any object that can cause reflections or shield the muzzle blast shall be mentioned. Such objects can be, for example, a part of the weapon, the support of the weapon or part of this support. Also, the gunman can be seen as a part of the weapon system that can shield the muzzle blast. All these elements, which are commonly used under normal operation of the weapon, shall be present during the measurement and shall be mentioned in the report. Other circumstances which can affect the noise source data shall also be reported. The gun shall be positioned as it would be under normal operating conditions. If the gun is put on a high support and fired with a rope, the shielding effect of the gunman is not taken into account. Therefore, it should be ensured that the experimental set up is as close to normal operation conditions as possible (see also 7.2).

4.6 Other features

All other information concerning the test conditions or anything that can affect measured source data shall be reported.

EXAMPLES

— the barrel in use in the case of a combination firearm, if the barrels have different features, especially bore;

— special features, like muzzle brakes, etc.;

— storage conditions of ammunition (temperature, humidity, duration, etc.).

5 Basic concept for measurement and analysis

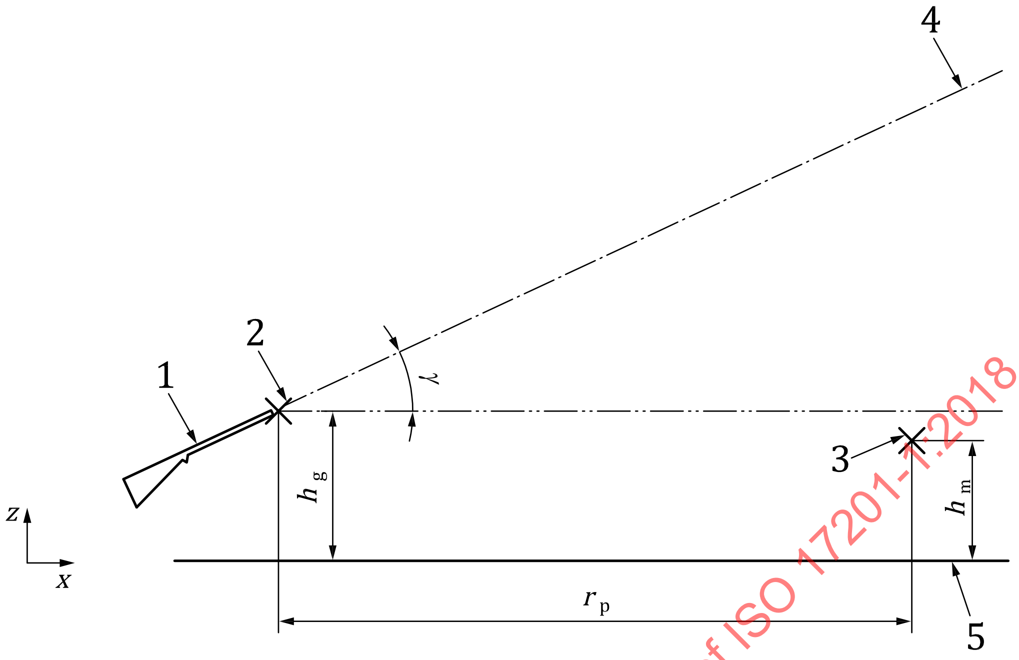
5.1 General

For the measurement of the muzzle blast, it is assumed that radiation of sound is rotationally symmetrical around the line of fire. This assumption is used to define spherical coordinates, r_m, α and β which are centred at the muzzle. The angles are defined in Clause 3.

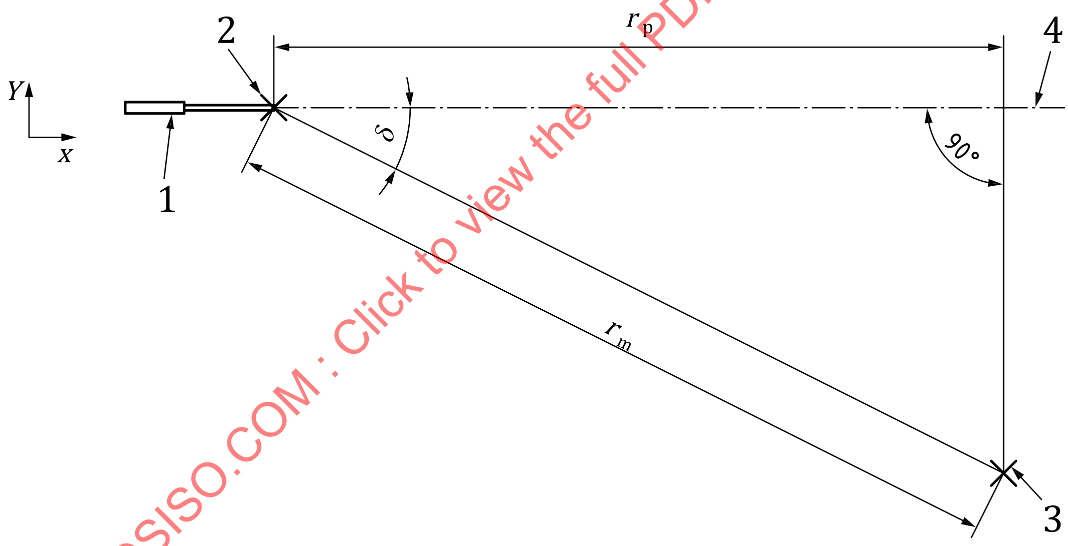
As the muzzle blast can be directional, measurements may be carried out on a circle. The goal is to measure the level and also the directivity pattern. An equal distance between measuring points makes it easier to use interpolation algorithms to get a continuous function for directivity pattern.

The measurements and the analyses shall yield spectral information in at least octave bands (preferably in one-third-octave-bands) from 31,5 Hz to 8 kHz.

The calculation method given in the 5.2 to 5.6 applies to broadband analysis as well as octave-band or one-third-octave-band analysis.



a) Side view



b) Top view

Key

1 gun

2 muzzle

3 microphone

4 line of fire

5 ground plane

NOTE 1 All distances are measured in meters.

NOTE 2 The relation between these angles is given below:

$$\cos(\alpha) = \cos(\gamma)\cos(\delta)\left[\frac{r_p + \tan(\gamma)(h_m - h_g)}{\sqrt{r_p^2 + \cos^2(\delta)(h_m - h_g)^2}}\right]$$

where

r_p is the projected distance on the ground plane from the muzzle to the microphone;

r_m is the distance from the muzzle to the microphone;

h_m is the height of the microphone above ground;

h_g is the height of the muzzle of the gun above ground.

Figure 3 — Angles γ and δ

5.2 Quantity to be measured

The basic quantity to be measured is the sound exposure level measured at a distance, r_m, and angles α and β

$$L_E(r_m,\alpha,\beta)=10\lg\int_{T_I}\frac{p^2(r_m,t,\alpha,\beta)}{p_0^2 T_{I_0}}\mathrm{d}t \quad \mathrm{dB} \tag{8}$$

where

T_I is the time interval, in seconds;

T_{I_0} is the reference time interval, $T_{I_0}=1\,\mathrm{s}$.

For further notation see Figure 3 and definitions (Clause 3).

Assuming rotational symmetry, the sound exposure level is a function of r_m and α alone.

However, due to ground reflections, when measuring above ground, the sound exposure level, L_E, also depends on β. The corrections to remove ground reflections are described in 9.2. After the corrections, the sound exposure level is assumed to depend on distance, r_m, and angle α only.

5.3 Angular source energy distribution level

The angular source energy distribution levels, $L_q(\alpha_n)$, are estimated on the basis of the sound exposure level measurements at N discrete angles, α_n, at the distance, r_m, by:

$$L_q(\alpha_n)=L_E(r_m,\alpha_n)+A_{div}(r_m)-11\,\mathrm{dB}+A_{atm}(r_m)+A_Z+A_{gr} \tag{9}$$

where

A_{div} is a correction that accounts for the geometric spread:

$$A_{div}=10\lg\left(\frac{r_m^2}{r_0^2}\right)\mathrm{dB}+11\,\mathrm{dB} \tag{10}$$

with r_0 = 1 m;

A_{atm} is a correction for air absorption (see ISO 9613-1);

A_{gr} is a correction in order to obtain free field condition (see 9.2 and Reference [15]);

NOTE This reference gives a simple algorithm to calculate the ground reflection of a spherical wave correctly, as described in Reference [16].

A_Z is used to correct for non-standard meteorological conditions (see ISO 3741, ISO 3745 and ISO 9614-3):

$$A_Z = -10 \lg \left(\frac{B T_0}{B_0 T} \right) \text{dB} \tag{11}$$

with

B is the air pressure under the condition of measurement;

B_0 is the reference air pressure, B_0 = 1 013 hPa;

T is the temperature under the condition of measurement;

T_0 is the reference temperature, T_0 = 296 K.

5.4 Interpolated angular source energy distribution level

In order to calculate the total source energy and to provide a continuous directivity function, a curve fitting for the angular source energy distribution level is needed. The curve-fitting methods used shall describe the periodic behaviour of the directivity function.

The angular source energy distribution level, $\bar{L}_q(\alpha)$, is obtained by interpolation and shall be reported as follows:

$$\bar{L}_q(\alpha) = a_0 + \sum_{j=1}^{N-1} a_j \cos(j\alpha) \tag{12}$$

where N is the number of terms used to describe $\bar{L}_q(\alpha)$.

NOTE 1 This formulation corresponds to an approach according to Fourier without Sine terms. As rotational symmetry is assumed, the Sine terms are zero.

NOTE 2 The parameters, a_j, can be obtained using Fourier Transformation, least-square fits or any other interpolation method.

For an example, see Annex B.

5.5 Source energy level

The source energy level is calculated from the interpolated angular source energy distribution levels by:

$$L_Q = 10 \lg \frac{1}{r_0^2} \left[\int_{\beta=0}^{2\pi} \int_{\alpha=0}^{\pi} 10^{0,1 \bar{L}_q(\alpha)} r_0 \sin\alpha \, \mathrm{d}\beta \, r_0 \, \mathrm{d}\alpha \right] \text{dB} \tag{13}$$

Since rotational symmetry is assumed, this can be written as:

$$L_Q = 10 \lg 2\pi \left[\int_{\alpha=0}^{\pi} 10^{0,1 \bar{L}_q(\alpha)} \sin\alpha \, \mathrm{d}\alpha \right] \text{dB} \tag{14}$$

5.6 Directivity

The directivity $D(\alpha)$ of the muzzle blast is given by:

$$D(\alpha) = \bar{L}_q(\alpha) - \left(L_Q - 10 \lg 4\pi \, \text{dB} \right) \tag{15}$$

6 Measurement site

6.1 Site

The measurement site shall be reasonably level, homogeneous with respect to the ground impedance, and free of objects that can cause reflections that affect the accuracy of the measurement.

EXAMPLE Examples of homogeneous grounds are:

— concrete,

— water,

— asphalt, and

— grass or sand.

6.2 Weather conditions

The average wind speed at 10 m height shall be less than 3 m/s.

The relative humidity shall be less than 95 %. The background level of wind-induced sound at the microphone should not be so great that it interferes with the measured signal at any frequency of interest.

7 Measurement planning

7.1 General remarks

Apart from the muzzle blast, the event signal may also include projectile sound, reflections from objects and from the ground. When planning a measurement, it should be taken into consideration how these "unwanted" contributions can be separated from the muzzle blast in the later data analysis. Commonly used methods are the following.

a) **Window technique**: This technique is applicable for signals that arrive at the microphone separated in time, where the width and position of the window is adjusted in such a way that only the sound from the muzzle blast can be analysed. It is typically used for reflecting objects and projectile sound. In a measurement layout with source and receiver heights that ensure a clear separation of the direct and the reflected wave from the ground, it can also be used to exclude the effect of ground reflections. In this case, it is $A_{gr} = 0$.

b) **Ground impedance models**: These models are used if the measured signal is a superposition of the direct wave and the reflected wave from the ground. They yield a prediction of the ground effect based on the reflection of a spherical wave at a complex impedance ground.

Other methods may also be used. The methods used shall be described.

7.2 Gun

The barrel should preferably be horizontal and at least 1,5 m above ground. In some directions, the projectile sound wave and the muzzle blast can be separated by window techniques. For directions where this is not possible, the correction may be computed. Projectile sound is also generated by projectiles from shot guns and pistols as long as the speed of these projectiles is supersonic.

7.3 Measurement position

The measurement positions can be arranged in either a semicircle or a full circle. The angular increment of angle α should preferably be regular. The angular increment should be 45° or less, see also Clause 10. One measurement position should be close to the line of fire. Care shall be taken not to choose measurement angles too close to the border of the projectile sound region. The difference in the averaged broadband sound exposure level of the frequency range of interest between adjacent measuring points shall be smaller than 5 dB. In order to reduce meteorological effects, the distance between the source and measurement positions should be chosen to be as short as possible.

The microphone should normally be placed at a distance of at least 10 m up to 50 m to ensure that the peak pressures do not exceed 1 kPa. It should be tested (considering the pressure limit of 1 kPa) at which distance the prerequisite is fulfilled. By increasing the measurement and source heights, the time delay between the direct and reflected signals can be increased.

7.4 Measurement equipment

Sound level meters and similar measurement instrumentation shall comply with the requirements for a class 1 instrument as specified in IEC 61672-1.

Compliance with additional requirements for the measurement of impulsive noise is recommended. Such requirements are specified in IEC 61672-1.

If a digital or analogue recording instrument is used for (intermediate) storage, it shall have an adequate bandwidth and dynamic range.

The measurement equipment, and in particular the measurement microphones, shall be suitable for measurement of high peak sound pressures. The potential to overload the microphones near to the trajectory should be taken into account.

7.5 Dealing with projectile sound

Projectile sound occurs when the speed of a projectile is supersonic. This is typical for rifles, but can also be observed with shotguns and pistols. Projectile sound only takes place in a distinct region in front of the weapon (the Mach area). The border of the Mach area at the muzzle is defined by the angle, ξ_0:

$$\xi_0 = \arccos\left(\frac{c}{v_0}\right) \qquad (16)$$

where

v_0 is the projectile speed at the muzzle;

c is the speed of sound under the conditions of measurement.

For a measurement position where α equals ξ_0, the signals from the muzzle sound and the projectile sound arrive at the same time and cannot be separated by time windowing. For measurement angles with α smaller than ξ_0, the projectile sound always arrives first and can be separated by time windowing. Care shall be taken not to choose a measurement position too close to the border of the Mach area to enable the necessary time gap for a separation. In the case of noise from shotguns, the time delay between the projectile sound and muzzle blast can be so small that time windowing or other techniques cannot be applied. However, the projectile moves with supersonic speed for only a short distance and its sound can be considered as coming from a point source. Therefore, the simultaneous inclusion of the projectile´s sound with the muzzle blast is acceptable. An increase of delay between the two signals may be achieved by increasing the measurement distance for the measurement positions within the Mach area (for details see ISO 17201-4).

8 Calibration and validation

System calibration shall include the response of all cables, amplifiers and accessories to be used when actual data are collected. Calibration shall be performed at appropriate times to ensure that the time-averaged sound pressure level can be measured over the entire dynamic range within the stated tolerance of the instrument. Acceptable acoustical calibration methods include the use of sound calibrators, acoustical shock sources or static pressure devices. Electrical calibration means are acceptable for field use, provided that acoustical calibration is accomplished before and after field use. Electrical signals should be applied to the microphone input via a suitable adapter.

The complete measurement chain shall be calibrated by the user at regular intervals and at least before and after a series of measurements at one frequency at least. The sound calibrator shall fulfil the requirements for a class 1 sound calibrator as specified in IEC 60942 under the actual environmental conditions.

The measurement instruments shall be checked regularly and shall be calibrated with traceability to a national standard.

For further guidance in calibrating for measurement of impulses, see ISO 10843.

9 Measurement procedures

9.1 General

At least five measurements of the sound exposure shall be made at each microphone position. The measured values of $E_T(\alpha, r_\mathrm{m})$ are averaged arithmetically (which means that the sound exposure levels are averaged energetically). It is preferred that simultaneous measurements be made at all microphone positions. Alternatively, measurements may be made sequentially but, as a minimum, two microphones should be used with one microphone always remaining at the same position.

If the peak sound pressure level exceeds 154 dB at any of the microphone positions, the measurement distance shall be increased. These peak sound pressure levels should preferably be read from the time/pressure signal, where the error due to limited high-frequency response of the equipment can be corrected.

9.2 Ground reflection correction

There are several methods to correct for the ground reflection. No corrections for ground reflection are necessary when windowing techniques are applied. Otherwise, the resulting levels shall be corrected to free-field conditions by applications of another suitable method (see, for example, Annex B). This document requires that the method and the corrections be recorded. If a method other than the one described in Annex B is used to determine the ground reflection, the value of A_gr in Formula (9) shall be changed correspondingly.

10 Control of measurement layout

To determine whether or not the number of measurement points is sufficient, the following procedure shall be applied.

Step 1: The source energy level, $L_Q{}^{(1)}$, is calculated using the interpolated angular source energy distribution level as given in Formula (12):

$$L_Q{}^{(1)} = 10\,\lg\left[2\pi \int_{\alpha=0}^{\pi} 10^{0{,}1\overline{L_q}(\alpha)} \sin\alpha \,\mathrm{d}\alpha\right] \mathrm{dB} \tag{17}$$

where the superscript 1 denotes this procedure.

Step 2: A source energy level, $L_Q^{(2)}$, is calculated from the interpolated angular source energy distribution, $\overline{S_q}(\alpha)$, as follows:

$$L_Q^{(2)} = 10\lg\left[\frac{2\pi}{Q_0}\int_{\alpha=0}^{\pi}\overline{S_q}(\alpha)\sin\alpha\,\mathrm{d}\alpha\right]\mathrm{dB} \tag{18}$$

where the superscript 2 denotes this procedure;

$\overline{S_q}(\alpha)$ is obtained with the same interpolation method used for the estimation of $\overline{L}_q(\alpha)$.

If the absolute value of the difference between $L_Q^{(1)}$ and $L_Q^{(2)}$ is 0,4 dB or less, the number of measured angular directions is considered to be sufficient:

$$\left|L_Q^{(1)} - L_Q^{(2)}\right| \le 0{,}4\,\mathrm{dB} \tag{19}$$

11 Measurement uncertainty

11.1 General

The measurement uncertainties associated with the source energy level and the directivity determined in accordance with this document shall be evaluated, preferably in compliance with ISO/IEC Guide 98-3.

The uncertainties arise in part from variations between test sites, changes in atmospheric conditions, geometry of the environment, acoustical properties of the ground, background noise, and the type and calibration of instrumentation. They are also due to variations in experimental techniques, including the number and location of microphone positions, sound source location and orientation, and determination of the corrections. In addition, uncertainties can occur if measurements are taken too close to the source; such uncertainties increase for smaller distances and lower frequencies.

The expanded measurement uncertainty together with the corresponding coverage factor shall be stated for a coverage probability of 95 % as defined in ISO/IEC Guide 98-3.

Guidance on how to express the uncertainty is given in Annex C.

11.2 Empirical part

This document provides two quantities to express the muzzle blast: the source energy level and its directivity. The contribution to the uncertainties from measurement as described above shall be estimated from the variance, s_D^2 of the directivity:

$$s_D^2 = \frac{1}{n\cdot m - N}\sum_{i=1}^{n}\sum_{j=1}^{m}\left[\overline{L}_q(\alpha_i) - L_{q,j}(\alpha_i)\right]^2 \tag{20}$$

where

m	is the number of repetitive measurements;
n	is the number of measured directions;
$L_{q,j}(\alpha_i)$	is the measured angular source energy distribution level, j, in direction α_i;
N	is the number of used coefficients in Formula (12) (see 5.4).

The uncertainty contribution, Δ_D, of the directivity is given by:

$$\Delta_D = \frac{s_D \cdot t(n \cdot m - N, P)}{\sqrt{m}} \tag{21}$$

where

t is the student factor; see Table 1 below;

P is the coverage probability (chosen to be 0,05).

Table 1 — Distribution of *t*-values in consideration of the number of degrees of freedom

Number of degrees of freedom	Coverage probability, *P* %	
	68,27	95
1	1,84	12,71
5	1,11	2,57
10	1,05	2,23
20	1,03	2,09
40	1,01	2,02
NOTE See Reference [15].		

For the source energy level, the equivalent uncertainty contribution is given by

$$\Delta_Q = \frac{s_D \cdot t(n \cdot m - 1, P)}{\sqrt{n \cdot m - 1}} \tag{22}$$

The uncertainty contributions given in Formulae (21) and (22) cover those of the measurement method used. They shall be supplemented by the uncertainty contribution resulting from the measurement of the sound exposure level, $L_E(r,\alpha)$, and the other quantities given in Formula (9). See Annex C for further guidance on measurement uncertainty.

An example is given in Annex B.

12 Report

The report shall document the primary data recorded (at least octave-band sound exposure and the peak sound pressure level of each shot) and reported, together with a description of the measurement and analysis conditions including measurement uncertainty (see Clause 11).

All measurement quantities shall be specified in SI units.

The height of the microphone above ground or relating to the sound source shall be stated.

The way in which the sound from supersonic projectiles and ground reflection have been eliminated, how the octave-band analysis has been performed, and which corrections were used shall be described. At least one example of the time/pressure signal for one measurement position shall be shown. The directivity patterns are given by listing the interpolation coefficient of Formula (12) for each frequency band.

All measurement equipment shall be specified, together with the date and result of the last traceable calibration. The guns and the ammunition shall be specified, as well as the meteorological conditions (wind speed, temperature, humidity, air pressure and cloud cover).

Annex A
(informative)

Small arms glossary

A.1 Glossary

Table A.1 — Terms and definitions

No	Term	Definition
A.1.1	**action**	combined parts of a firearm that determine how a firearm is loaded, discharged and unloaded NOTE Most handguns are referred to as "single-action" or "double-action." A single-action firearm requires the user to manually pull back the hammer before the firearm can be discharged (like the old western revolvers). A double-action firearm allows the user to either manually cock the hammer or simply pull the trigger and allow the firearm to cock and release the hammer on its own.
A.1.2	**automatic action**	firearm that loads, fires and ejects cartridges as long as the trigger is depressed and there are cartridges available in the feeding system (i.e. magazine or other such mechanism) NOTE Automatic action firearms are machine guns[a].
A.1.3	**automatic pistol**	common but improperly used term to describe semi-automatic pistols NOTE See semi-automatic action for a description of how these pistols operate.
A.1.4	**black powder firearms**	see muzzle loader (A.1.24)
A.1.5	**bolt action**	firearm, typically a rifle, that is manually loaded, cocked and unloaded by pulling a bolt mechanism up and back to eject a spent cartridge and load another NOTE Bolt-action firearms are popular for hunting, target shooting and biathlon events. A bolt-action rifle allows the shooter maximum accuracy, but may be too slow or cumbersome for some shooting sports.
A.1.6	**bore diameter**	<rifled barrels> minor interior diameter of a barrel which is the diameter of a circle formed by the tops of the lands in a rifled barrel <shotguns> interior dimension of the barrel forward of the chamber but before the choke
A.1.7	**breech face**	part of the breech block which is against the head of the cartridge case or shot shell during feeding and firing NOTE Breech face is sometimes called breech block face.
A.1.8	**calibre**	term used to designate the specific cartridges for which a firearm is chambered NOTE It is the approximate diameter of the circle formed by the tops of the lands of a rifled barrel. It is the numerical term included in the cartridge name to indicate a rough approximation of the projectile diameter (i.e. 30 calibre).
A.1.9	**carbine**	rifle of short length and light mass, originally designed for horse-mounted troops

[a] Some jurisdictions or countries may regulate the sale and possession of automatic firearms, for example, since 1934 it has been unlawful to sell or possess an automatic firearm without special permission and licensing from the U.S. Department of the Treasury, in addition to other measures.

Table A.1 *(continued)*

No	Term	Definition
A.1.10	**chamber**	<rifle, shotgun or pistol> part of the barrel bore that has been formed to accept a specific cartridge or shell <revolver> holes in the cylinder that have been formed to accept a specific cartridge
A.1.11	**choke**	interior constriction at or near the muzzle end of a shotgun barrel for the purpose of controlling shot dispersion
A.1.12	**choke margin**	portion of the choke forward of the greater constriction (see Table A.2)
A.1.13	**compensator**	device attached to the muzzle end of the barrel that utilizes propelling gases to reduce recoil or noise or both See also muzzle brake (A.1.25).
A.1.14	**cone, forcing**	tapered lead from the shotgun chamber diameter to the bore diameter, tapered lead from the bore diameter to the choke diameter, or tapered lead entrance to the bore in the rear of a revolver barrel
A.1.15	**explosive charge**	a quantity of explosive to be set off at one time NOTE "g TNT" equivalent is a convention for expressing energy, typically used to describe the energy released in an explosion. 1 g TNT equivalent is the energy released in the explosion of 1 g of TNT.
A.1.16	**firearm**	assembly of a barrel and action from which a projectile is propelled as a a result of combustion
A.1.17	**gauge**	term relating to the number of bore diameter lead balls weighing 1 Ib NOTE It is a term used to identify most shotgun bores, with the exception of the 410 shotgun, which has a calibre of 0,410 inches".
A.1.18	**groove diameter**	major diameter in a barrel which is the diameter of a circle circumscripted by the bottom of the grooves in a rifled barrel
A.1.19	**grooves**	see rifling (A.1.32)
A.1.20	**handgun**	firearm designed to be held and fired with one hand
A.1.21	**headspace**	distance from the face of the closed breech of a firearm to the surface in the chamber on which the cartridge seats
A.1.22	**locked breech action**	any action wherein the breech bolt is locked to the barrel or receiver, through a portion or all of the recoiling motion
A.1.23	**machine gun**	see automatic action (A.1.2)
A.1.24	**muzzle loader**	any firearm loaded through the muzzle NOTE Also called "black powder" firearms. They may be antique, replica or of modern design.
A.1.25	**muzzle brake**	device at the muzzle end, usually integral with the barrel, that uses the emerging gas behind a projectile to reduce recoil; see also compensator (A.1.13).
A.1.26	**over and under**	firearm with two barrels, one above the other
A.1.27	**pistol**	handgun in which the chamber is part of the barrel
A.1.28	**pump action**	firearm that features a movable forearm that is manually actuated to chamber a round, eject the casing and put another round in position to fire
A.1.29	**pump gun**	see pump action (A.1.28)
A.1.30	**revolver**	firearm, usually a handgun, with a cylinder having several chambers so arranged as to rotate around an axis and be discharged successively by the same firing mechanism

[a] Some jurisdictions or countries may regulate the sale and possession of automatic firearms, for example, since 1934 it has been unlawful to sell or possess an automatic firearm without special permission and licensing from the U.S. Department of the Treasury, in addition to other measures.

Table A.1 *(continued)*

No	Term	Definition
A.1.31	**rifle**	firearm having spiral grooves in the bore and designed to be fired from the shoulder
A.1.32	**rifling**	grooves formed in the bore of firearm barrel to impart rotary motion to a projectile
A.1.33	**semi-automatic**	firearm which fires, extracts, ejects and reloads only once for each pull and release of the trigger
A.1.34	**semi-automatic action**	firearm in which each pull of the trigger results in a complete firing cycle, from discharge through reloading NOTE 1 It is necessary that the trigger be released and pulled for each cycle. These firearms are also called "autoloaders" or "self-loaders." The discharge and chambering of a round is blow-back operated, recoil operated, or gas operated. NOTE 2 An automatic action firearm loads, discharges and reloads as long as ammunition is available and the trigger is depressed. A semi-automatic firearm only discharges one cartridge with each squeeze of the trigger.
A.1.35	**shotgun**	smooth bore shoulder firearm designed to fire shells containing numerous pellets or a single slug
A.1.36	**twist**	distance required for one complete turn of rifling, usually expressed as a ratio

[a] Some jurisdictions or countries may regulate the sale and possession of automatic firearms, for example, since 1934 it has been unlawful to sell or possess an automatic firearm without special permission and licensing from the U.S. Department of the Treasury, in addition to other measures.

Table A.2 — Choke margins in Europe and United States

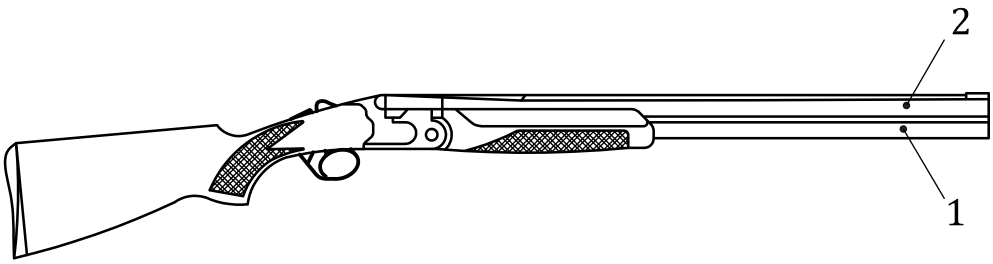
Choke margin	Choke markings, Europe	Choke markings, United States
Full choke	*	FC, Full (greatest constriction)
Improved-modified	**	Imp. Mod. (less constriction)
Modified	***	Mod. (less constriction)
Improved cylinder	****	IC, Imp. Cyl. (less constriction)
Cylinder	CL	
Skeet		Skeet, Sk (less constriction)
Cylinder bore		Cyl. (least constriction)

NOTE Some firearm manufacturers in the United States also use the European system.

A.2 Examples of firearms

A.2.1 Smooth-bore barrelled firearms

Figure A.1 — Single-shot shotgun

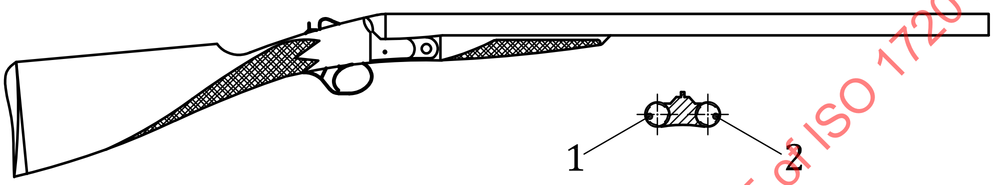


Key

1 bottom barrel

2 top barrel

Figure A.2 — Over-and-under shotgun



Key

1 left barrel (shooter's view)

2 right barrel (shooter's view)

Figure A.3 — Side-to-side shotgun

Figure A.4 — Pump gun

Figure A.5 — Semi-automatic shotgun (locked breech action)

A.2.2 Combination smoothbore and rifled barrelled firearms

Key

1 top barrel

2 bottom barrel

Figure A.6 — Over-and-under combination

Key

1 left barrel (shooter's view)

2 right barrel (shooter's view)

Figure A.7 — Side-to-side combination

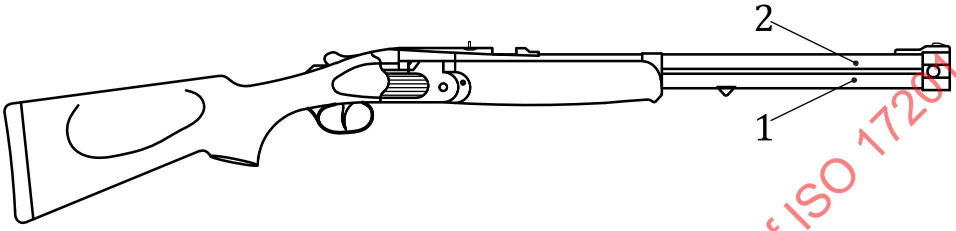
Key

1 two rifled barrels one smooth-bore barrel, or two smooth-bore barrels and one rifled barrel

Figure A.8 — Drilling/three-barrelled gun

A.2.3 Rifled barrelled firearms

Figure A.9 — Single-shot rifle



Key

1 bottom barrel

2 top barrel

Figure A.10 — Express double rifle

Figure A.11 — Semi-automatic rifle with locked breech action

Figure A.12 — Semi-automatic rifle with blow-back action

Figure A.13 — Bolt-action rifle

Figure A.14 — Submachine gun with blow-back action

Figure A.15 — Assault rifle (automatic rifle with locked breech action)

Figure A.16 — Machine gun with locked breech action

A.2.4 Pistols and revolvers

Figure A.17 — Semi-automatic pistol with locked breech action

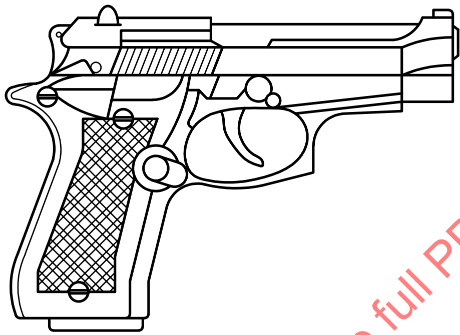
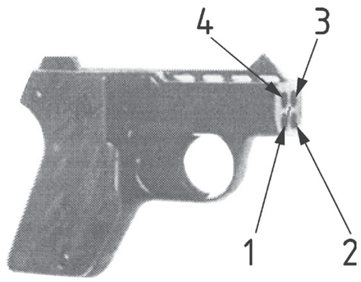


Figure A.18 — Semi-automatic pistol with blow-back action

Figure A.19 — Single-action revolver



Key

1 bottom right barrel
2 bottom left barrel
3 top left barrel
4 top right barrel

Figure A.20 — Multi-barrel handgun

Figure A.21 — Double-action revolver

A.2.5 Black powder firearms

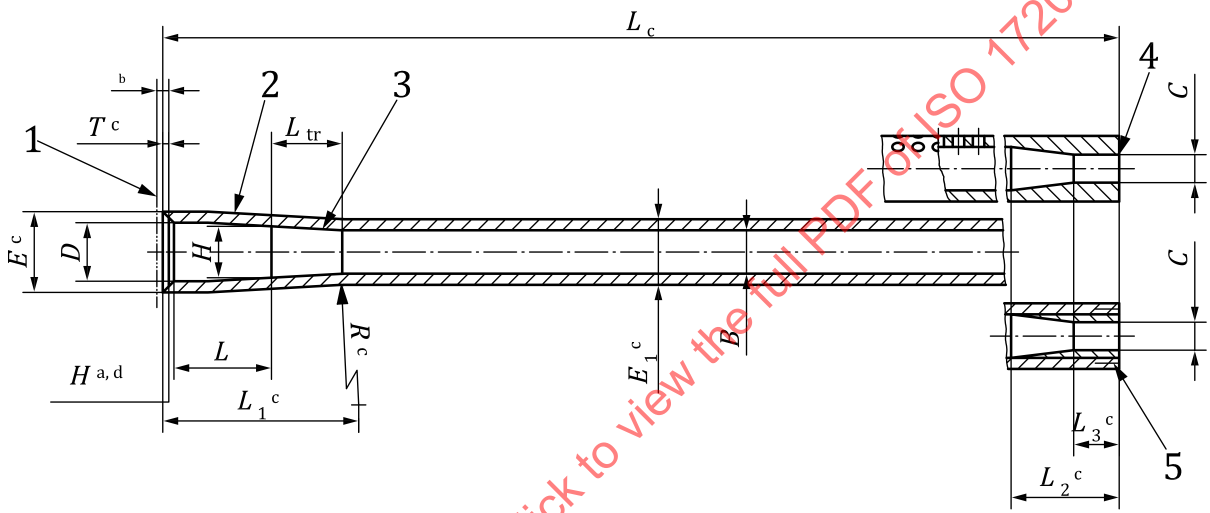
Figure A.22 — Muzzle-loading rifle

Figure A.23 — Muzzle-loading pistol

Figure A.24 — Muzzle-loading revolver

A.3 Barrels

A.3.1 Smooth-bore barrel



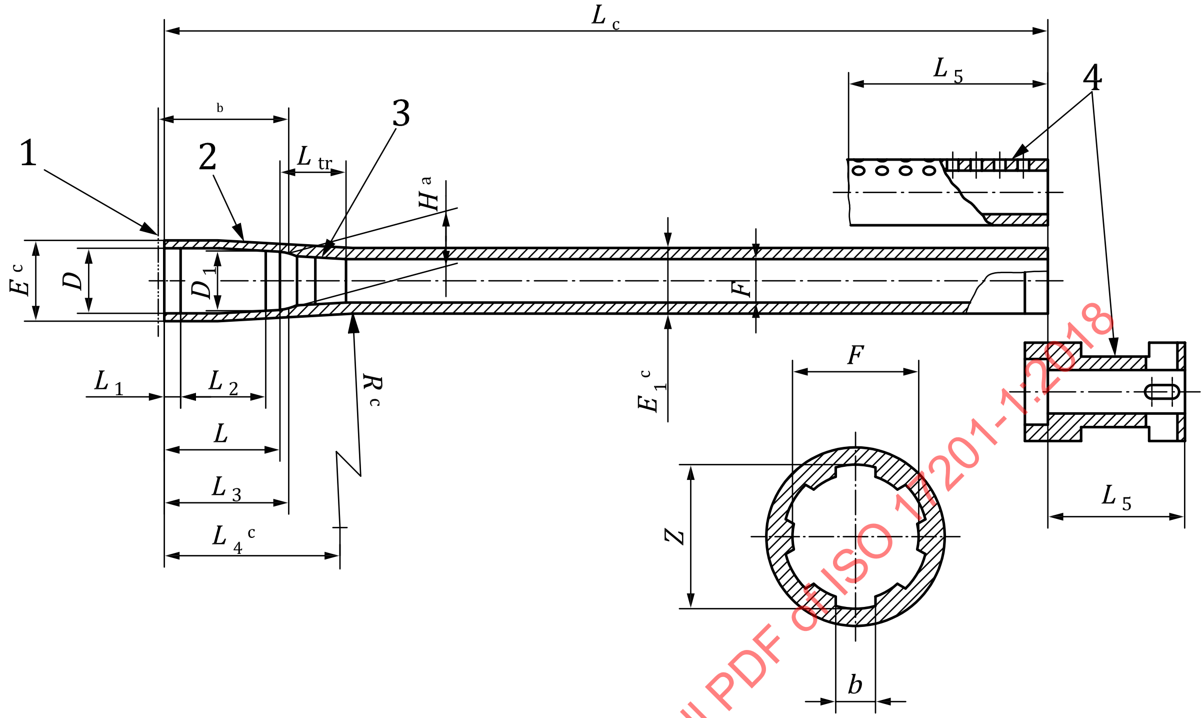
Key

1 breech (block) face
2 chamber
3 forcing cone
4 choke
5 mobile choke
a It is basic.
b It is headspace dimension.
c It is the manufacturer´s dimension.

ID	Definitions	Notes
D	First chamber diameter	
H	Second chamber diameter	
L	Chamber length	
B	Bore diameter	
C	Choke diameter	$C = B$ – constriction value
L_C	Barrel length	
E, E_1	External diameter	

Figure A.25 — Smooth-bore barrel

A.3.2 Rifled barrel



Key

1 breech (block) face

2 chamber

3 chamber lead

4 muzzle brake or flash hider or any muzzle device

a It is basic.

b It is headspace dimension.

c It is the manufacturer´s dimension.

ID	Definitions
D	First chamber diameter
D_1	Second chamber diameter
L	Chamber length
L_1	Distance of D from barrel rear end face
L_2	Distance between chamber diameters (D, D_1)
H	Basic shoulder diameter
L_3	Distance of H from barrel rear end face
L_{tr}	Chamber lead length
F	Bore diameter
Z	Groove diameter
b	Groove width
	Number of grooves
	Twist
	Groove area
L_C	Barrel length
E, E_1	External diameter

Figure A.26 — Rifled barrel

Annex B
(informative)

Example

B.1 Measurement positions

The muzzle blast of a shotgun using a 0,67 m full-choked barrel and a charge of 24 g of lead pellets was measured. The gun was mounted on a vice in such a way that the muzzle was positioned within 1,5 m ± 0,03 m above ground. The ¼ inch microphones were positioned on a semicircle at a distance of 10 m, at a height of 1,5 m above ground, using a microphone orientation for grazing incidence. The ammunition was manufactured in such a way that the average pellet speed at the muzzle was 400 m/s. The ammunition was stored under standard conditions in an air-conditioned container. The angle of the line of fire with the ground was equal to zero.

The angular increment was chosen to be 30°. From the semi-circular array pattern, the 0 ° microphone was further displaced 0,25 m perpendicular to the line of fire. The distance of all positions was checked using blanks from a revolver. The microphone position was adapted until the muzzle blast signal of the blank showed the same time delay as the signal for the zero position. Additionally, the 15° position was measured. Microphones were placed at angles 0°, 15°, 30°, 60°, 90°, 120°, 150° and 180° from the direction of the fire, subtended at the muzzle. The muzzle is located in the centre.

B.2 Measured data

The data given in Table B.1 were obtained from the measured sound pressure using Fourier transform to obtain the following frequency bands.

Table B.1 — Measured Z-weighted angular sound exposure level in decibels

Angle degrees	31,5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 000 Hz	2 000 Hz	4 000 Hz	8 000 Hz
0	90,6	96,9	98,2	107,9	112,5	112,5	113,8	112,4	109,7
0	88,0	95,3	94,9	108,5	112,3	113,7	111,7	110,3	107,9
0	87,9	96,7	101,0	103,8	111,3	112,8	114,2	111,7	108,3
0	89,2	97,8	100,3	107,2	113,2	114,3	111,8	112,6	107,8
0	88,1	97,8	101,9	104,0	111,7	114,1	111,9	109,7	106,0
15	87,6	96,4	102,1	99,3	105,7	111,3	106,3	105,0	103,8
15	86,4	95,6	101,5	97,9	106,2	110,6	108,5	106,0	103,9
15	86,5	95,7	102,3	101,3	105,8	109,4	107,6	103,9	102,9
15	87,1	96,5	102,2	99,9	105,3	112,8	107,7	104,7	104,4
15	87,0	96,0	102,2	100,7	104,2	109,3	106,4	105,3	101,4
30	85,0	93,9	101,1	101,1	108,6	108,2	105,1	99,4	97,2
30	84,9	93,7	100,9	101,0	109,4	106,7	102,9	99,3	95,2
30	84,9	94,0	101,1	101,2	109,0	108,3	104,8	100,9	97,6
30	84,8	94,1	101,2	100,9	108,9	108,4	102,9	102,0	100,3
30	85,4	94,0	101,0	100,6	108,3	108,9	103,5	101,0	94,5
60	78,5	88,3	95,8	95,4	98,6	100,3	99,3	98,5	94,7
60	78,8	87,8	95,5	95,2	98,4	99,7	98,8	96,2	94,0

Table B.1 *(continued)*

Angle degrees	**31,5** Hz	**63** Hz	**125** Hz	**250** Hz	**500** Hz	**1 000** Hz	**2 000** Hz	**4 000** Hz	**8 000** Hz
60	79,4	88,2	95,5	95,4	99,4	98,6	100,5	97,5	93,1
60	78,8	87,7	95,4	95,0	99,5	98,9	98,7	96,5	94,2
60	78,9	88,4	95,5	94,9	98,9	98,7	99,3	98,1	95,2
90	72,9	83,3	89,9	88,2	96,9	96,2	95,9	93,3	90,5
90	74,1	82,9	90,1	88,3	96,6	96,5	94,0	93,2	89,7
90	72,9	83,5	90,1	87,9	96,6	96,2	94,6	91,5	91,0
90	73,3	83,8	90,5	88,3	97,2	96,9	95,8	92,3	90,6
90	73,0	83,6	90,1	88,1	96,3	95,7	93,7	91,3	90,8
120	68,9	78,6	85,1	83,7	92,3	92,1	91,3	91,5	89,4
120	69,1	79,5	85,5	84,1	91,9	92,8	91,7	91,1	89,0
120	70,7	79,7	85,3	84,0	92,0	92,4	92,4	92,1	89,8
120	71,2	80,1	85,5	84,1	92,0	91,6	89,2	92,1	89,2
120	71,3	80,0	85,3	83,8	91,8	93,2	92,7	92,7	89,1
150	64,9	75,1	82,1	84,0	88,7	87,5	86,9	82,6	78,2
150	67,9	77,0	82,4	83,9	88,2	87,8	87,5	85,6	80,0
150	67,5	76,8	82,0	83,4	86,3	87,8	89,5	87,0	87,0
150	67,3	77,6	82,9	84,0	88,4	87,7	87,1	84,3	81,2
150	65,9	77,0	82,5	84,0	87,8	88,4	87,8	87,6	85,0
180	63,3	74,5	80,8	79,5	90,6	90,5	91,5	86,5	86,3
180	63,8	74,0	80,7	81,0	88,2	90,8	89,5	86,3	84,6
180	64,5	74,3	81,1	81,5	87,4	88,4	89,7	84,7	82,9
180	64,4	75,8	81,3	81,1	89,5	91,5	89,3	89,6	86,2
180	63,0	74,6	81,4	81,8	88,0	90,0	90,8	88,4	85,0

B.3 Removal of projectile sound

The sound pressures at 0°, 15° and 60° are depicted in Figure B.1. The time shift between the projectile sound and the muzzle blast for each of these signals is smaller than 2 ms. Because of the small time shift time windowing does not work. Therefore no correction was taken.

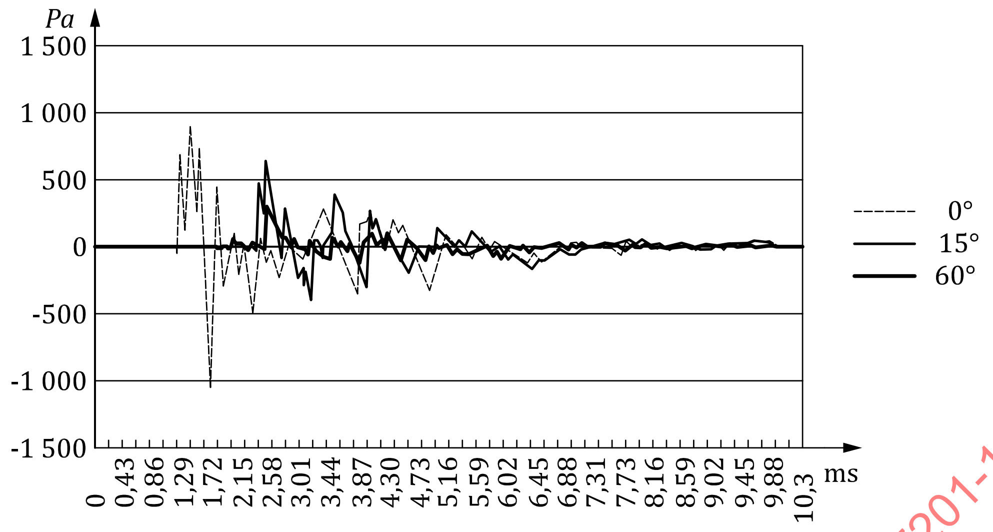


Figure B.1 — Measured sound pressure at 0°, 15° and 60° for 0,67 m chocked barrel, 24 g pellets, muzzle speed 400 m/s

B.4 Removal of ground reflection

The ground effect was corrected by the values given in Table B.2, derived from the measured impedance at the site after the measurements were performed. The interference minimum was measured. Varying the flow resistance and the penetration depth in a sound propagation model, based on Reference [15] the ground impedance was obtained.

Table B.2 — Correction for ground reflection

Frequency, Hz	31,5	63	125	250	500	1 000	2 000	4 000	8 000
Ground reflection, dB	−5,2	−5,2	−3,4	2,7	−1,5	−1,5	−1,1	0,9	0,9
NOTE See Reference [15].									

B.5 Corrected measurement data

The measured data were averaged and corrected for the ground reflection (see Table B.3):

Table B.3 — Averaged A-weighted levels after the removal of ground reflection

Direction angle degrees	Averaged levels dB	31,5 Hz dB	63 Hz dB	125 Hz dB	250 Hz dB	500 Hz dB	1 000 Hz dB	2 000 Hz dB	4 000 Hz dB	8 000 Hz dB
0	118,0	83,7	91,8	96,5	109,4	110,8	112,0	111,7	110,6	108,7
15	112,9	81,6	90,8	98,8	102,4	103,8	109,2	105,9	103,6	103,5
30	110,7	79,7	88,6	97,5	103,8	107,5	106,4	102,7	99,6	97,8
60	104,1	73,5	82,7	92,0	97,6	97,2	97,6	98,1	96,4	94,8
90	100,3	67,9	78,1	86,6	90,7	95,2	94,8	93,7	91,4	91,1
120	97,5	65,1	74,3	81,8	86,6	90,3	90,8	90,4	90,9	89,8
150	92,9	61,5	71,5	78,9	86,5	86,4	86,4	86,8	84,8	84,0
180	94,8	58,7	69,5	77,7	83,8	87,4	88,8	89,1	86,5	85,7

